

Issel. Two other species (*Pholas dactylus*, L., and *Solen vagina*, L.) had reached Ismailia. One could wish it were not so proverbially difficult to prove a negative; for, if *Maestra olorina* and *Mytilus variabilis* did not exist at Port Said, or in any part of the Mediterranean, prior to the opening of the Suez Canal (and in the total absence of evidence the other way, one may fairly assume this to have been the case), their passage from one sea to the other in the short space of thirteen years is an event remarkable in the history of distribution. It will be interesting, too, to notice whether the species in question have undergone, or are undergoing variations as a result of their change of locality.

XXXIX.—*Note on the Structure of Crotalocrinus.* By P. HERBERT CARPENTER, D.Sc., F.R.S., F.L.S., Assistant Master at Eton College.

THE third part of Messrs. Wachsmuth and Springer's "Revision of the Palæocrinoidea," the second section of which has recently appeared*, contains the following statement respecting the suborder "Articulata," which, as defined by the authors, includes the family Ichthyocrinidæ, together with the three genera *Crotalocrinus*, *Enallocrinus*, and *Cleioocrinus*:—

"We maintain, however, that the outer test of the ventral side in this group was a continuous integument, composed of calcareous plates, united by ligament and not by a close suture, and that by reason of this structure and the articulation among the plates of the dorsal side it must have been pliant or flexible. . . . That there was an inner integument roofed in and covered by the flexible vault we have mentioned, and that it contained the summit-plates and 'covering pieces,' we know to be true in the *Crotalocrinidæ*, and we think it altogether probable that the general plan of the ventral structure for the *Articulata* generally is expressed in that of *Crotalocrinus*."

This last paragraph contains a somewhat positive and emphatic statement. The authors "know it to be true" that *Crotalocrinus* had a flexible vault above the summit-plates, which, be it remembered, themselves covered in the disk on which the peristome and ambulacra were situated. It has generally been considered hitherto that the summit-plates of

* Proc. Acad. Nat. Sci. Philad., March 30, 1886, p. 64. The paging of the separate copy is 140, and in future references the pagination of the entire work will be quoted, not that of the Philadelphia "Proceedings."

a Palæocrinoid, like the calyx-plates of the dorsal side, with which they were universally regarded as homologous, were placed on the extreme outside of the body, nothing but a thin film of perisome, covered by a pavement epithelium, intervening between the plates and the surrounding water. But we are now told as a positive fact, on the authority of Messrs. Wachsmuth and Springer, than which there is none higher, that *Crotalocrinus* and the Ichthyocrinidæ (a family which in many respects approaches the Neocrinoids more closely than any other Palæozoic forms) possessed the anomalous character of two vaults above the visceral mass—an inner one containing the actinal summit-plates and the covering plates, like the vault of *Platycrinus*, and an outer one of a more flexible character and composed of smaller plates belonging to the abactinal system.

Let us examine into the evidence which has led Wachsmuth and Springer to make this assertion. Neither *Crotalocrinus* nor *Enallocrinus* occurs in America; but both genera are found in the Silurian of the island of Gotland, and *Crotalocrinus* also occurs in the Dudley Limestone of this country. The National Museums of London and Stockholm contain remarkably fine specimens of these types, but unfortunately they have not been examined by Wachsmuth and Springer, whose knowledge of *Crotalocrinus* and *Enallocrinus* is principally, if not entirely, confined to the figures published by Müller, Angelin, and other authors; and I have a very strong conviction that the remarkable statement to which they have committed themselves so positively is due to a misinterpretation of these figures. By the kindness of Prof. G. Lindström I was able to examine the originals of many of Angelin's figures during a recent visit to Stockholm; and the examples of *Crotalocrinus* from Dudley, which are in the National Collection at South Kensington, have also come under my observation. These opportunities have convinced me that the "pliant vault" above the summit-plates, which is described by Wachsmuth and Springer in *Crotalocrinus*, had no existence in reality. They say on pp. 18 and 19 of part iii.:—

"In the Crotalocrinidæ, which include *Crotalocrinus* and *Enallocrinus*, the whole ventral surface, in what appear to be the best-preserved specimens, is composed of strong convex plates, without definite arrangement. In these specimens there is no central piece, nor proximals, nor traces of ambulacra (Icon. Crin. Suec., pl. 7, fig. 3 a; pl. 8, figs. 6, 7, and pl. 25, fig. 2); there are, however, other figures of Angelin, apparently of a closely allied species (Ibid. pl. 17, fig. 3 a), in which the plates paving the ventral surface are much more delicate, and consist of a central plate, large proximals,

and several rows of covering pieces, without the intervention of either anambulacral or interrarial pieces. It would be difficult with the utmost stretch of our imagination to recognize in the former figures either proximals or central piece, which, as admitted by Carpenter, are present in all these Crinoids, and we think there can be little doubt that the two sets of figures represent different parts of the animal, the one the disk, the other the vault, and that the one covered the other. A similar opinion was evidently entertained by Zittel (Handb. d. Palæont., i. p. 357), who stated that *Crotalocrinus* possessed five 'grosse Oralplatten, bald unter der Decke, bald äusserlich sichtbar.' According to our interpretation the calyx of the *Crotalocrinidæ* extends ventrally to the oral pole, and the ambulacra, central piece, and proximals are subtegmina, covered by interrarial plates, which extend out to the lower rows of covering plates and side pieces (Icon. Crin. Suec., pl. 7, fig. 6, and pl. 25, fig. 15). A similar condition probably prevailed in the *Ichthyocrinidæ*, with which the *Crotalocrinidæ* have close affinities."

Of Angelin's four figures first referred to by Wachsmuth and Springer in the above paragraph, the first and last (tab. vii. fig. 3 a, and tab. xxv. fig. 2) represent *Enallocrinus scriptus*, and the other two (tab. viii. figs. 6 & 7) *Crotalocrinus pulcher*. Fig. 3 a on tab. xvii. represents the vault of *Crotalocrinus rugosus*, and the central plate with the four anterior proximals is very distinct, as admitted by Wachsmuth and Springer. But when they state that "there is no central piece, nor proximals, nor traces of ambulacra" in the figures of *Crotalocrinus pulcher* and *Enallocrinus scriptus* they appear to me to be seriously in error.

No one knows better than the American authors that while the summit-plates are clear and well defined in some species and genera, there are other closely allied forms in which these plates are almost or entirely undistinguishable among the large number of plates to be found in the vault. I will now only mention one instance in illustration of this statement, viz. *Cyathocrinus iowensis* and *C. multibrachiatus*, both of which are figured by Wachsmuth and Springer*, the former with and the latter without very distinct summit-plates; and I might name any number of similar cases in the arrangement of the plates of the Echinoderm apical system, especially among the Ophiurids.

But the argument used by Wachsmuth and Springer is of this kind:—1. The vault of *Crotalocrinus pulcher* and of *Enallocrinus scriptus* is composed of irregularly disposed plates, none of which are specially distinguishable as the summit-plates. 2. The vault of *Crotalocrinus rugosus*, how-

* 'Revision,' part iii. p. 65, pl. iv. fig. 6, and pl. v. fig. 7.

ever, contains distinct summit-plates belonging to the actinal system. 3. Therefore it is an "inner integument," and was in reality covered by a "flexible vault" composed of irregularly disposed plates belonging to the interrarial portion of the calyx or abactinal system, such as form the external covering or vault of *Crotalocrinus pulcher* and *Enallocrinus scriptus*.

The logic of this argument does not appear to me to be so sound that Messrs. Wachsmuth and Springer are entitled to say of their conclusion that they "know it to be true." It will be quite time enough to say this when they have discovered *either* the "inner integument" in *Crotalocrinus pulcher* or in *Enallocrinus scriptus*, or the "flexible vault" above this integument in *Crotalocrinus rugosus*; but from my own observation of two specimens of this latter type, both of them better preserved than that figured by Angelin, I feel myself entitled to say without fear of contradiction that the central plate and proximals were never covered up by such a "flexible vault" as that of which the existence is "known to be true" by Messrs. Wachsmuth and Springer.

For the sake of brevity I pass over their references to the absence of ambulacra in the summit of *Crotalocrinus pulcher* and *Enallocrinus scriptus*, as figured by Angelin, and to the opinions of Zittel respecting the oral plates of *Crotalocrinus*—both of them points which are open to a considerable amount of discussion—and I will pass on to the other evidence which the American authors adduce in favour of their theory that the central summit-plate and proximals of *Crotalocrinus*, together with "the entire ventral surface"*, were covered by calyx-interradials extending upwards from the abactinal side, where, by the way, "only occasionally the first interrarial is visible dorsally"†.

At the conclusion of the long paragraph quoted above, tab. vii. fig. 6 and tab. xxv. fig. 15 of Angelin's work are referred to in illustration of this theory; but fig. 6 on tab. vii. simply represents a side view of the calyx of *Crotalocrinus pulcher*, and I strongly suspect that the authors meant to quote fig. 6 on tab. viii., the summit view of this species to which I have just referred. They continue on p. 64 of part iii. :—

"The vault of the Crotalocrinidæ extends quite a distance into the free rays, as shown by Müller's and Angelin's figures (Iconogr., pl. 6, figs. 6 and 7, also pl. 25, figs. 15 and 25, and Akademie der Wissenschaften, 1853, pl. 13, fig. 10). That those plates are not ambulacral pieces is proved by the fact that they cover the Saumplatten, and have a different style of ornamentation. Those

* 'Revision,' part iii. pp. 57 and 143.

† *Ibid.* p. 149.

figures further prove that the ventral covering was pliable, or the arms could not have assumed that horizontal position and be folded in other specimens."

It is unfortunate that of the five figures referred to in the first sentence of the above passage only one is quoted correctly, viz. tab. xxv. fig. 15. The last figure on this plate is 20, and I am therefore at a loss to know which one is meant by pl. 25, fig. 25. Figs. 6 and 7 on tab. vi. represent *Eucriinus interradialis* and *E. ornatus*, and I strongly suspect that, as in the previous case, tab. viii. is the one to which the authors meant to refer; while Taf. viii. fig. 10 would have been a more correct citation of the figure of *Crotalocrinus pulcher* in Müller's memoir, "Ueber den Bau der Echinodermen," which is only illustrated by nine and not by thirteen plates.

It is to this latter figure and to fig. 15 on tab. xxv. of Angelin's work that I now wish to direct attention; for they are the two on which Wachsmuth and Springer especially rely as proving that the calyx-interradials of *Crotalocrinus*, which are so slightly developed on the dorsal side, not only cover the oral pole, but also extend out on to the free rays and roof in the ambulacral covering plates on their ventral side*.

Most unfortunately, however, for the theory of the American authors, the figures in question represent *dorsal* and not *ventral* views of the "free rays," and their supposed "pliable ventral covering" formed of interradial plates consists of nothing but the arm-joints themselves. These are seen in their dorsal aspect at one end of Angelin's figure (which I have copied), but are removed elsewhere. This fact is fully explained by the three authors whom Wachsmuth and Springer quote, viz. Müller, Angelin, and Zittel; and it can only have been due to some extraordinary oversight on the part of the American writers that they allowed it to escape their notice. The result is an attempt to support their theory respecting the interradials of the Palæocrinoids by describing the *antiambulacral* arm-joints, which are nothing if not *radial*, as *superambulacral interradials*! But this theory breaks down altogether, so far as *Crotalocrinus* is concerned, when tested by facts.

Thus, for example, Müller says of his Taf. viii. fig. 10, "Strahlen der Hand, an welchen die Körper der Glieder zum Theil abgebrochen sind, so dass die kleinen Täfelchen an der Bauchseite der Glieder sichtbar sind."

In like manner Angelin, whose figure I have copied (see p. 402), explained it as follows:—"Squamulæ tessellatæ ambu-

* Compare also the description of the "interradials" in the generic diagnosis of *Crotalocrinus* on p. 149 of the 'Revision,' part iii.

lacrorum subtus visæ, assulis connatis inferioribus brachii maximam partem demtis" *. Zittel, who gives a copy of



Portion of a free ray of *Crotalocrinus pulcher*, seen from the dorsal side. The arm-joints (interradials, W. & S.) are preserved at the proximal end of the specimen; but they have partially fallen away at the distal end, so as to expose the inferior or dorsal surfaces of the ambulacral covering plates. (After Angelin.)

this very same figure †, is still more explicit in his explanation of it:—"Die Armstücke von der Rückenseite, um die Verbindung derselben zu zeigen; gegen oben sind die Dorsalstücke weggebrochen und nur die Saumplatten und die Decktäfelchen der Ambulacralrinne von unten zu sehen."

So far then as the free rays of *Crotalocrinus* are concerned I do not think that Wachsmuth and Springer will again venture to assert that the covering plates were roofed over by a "pliable ventral covering" formed of calyx-interradials; and much of the following argument from pages 64 and 65 of part iii. is therefore altogether worthless:—

"This is of some importance as demonstrating that a pliable vault may enclose another flexible integument and contain the food-grooves underneath, which was seriously questioned by Carpenter (Chall. Rep., p. 182). He evidently overlooked *Crotalocrinus*, for we doubt if he could have taken the small covering plates (Icongr., pl. 17, fig. 3 a) for the representatives of the large rigid plates ‡ of figs. 6 and 7 on pl. 6, or the irregular pieces around the oral pole to be summit-plates."

It seems to me that the charge which Wachsmuth and Springer bring against me of having "evidently overlooked *Crotalocrinus*" has treated them like the proverbial chicken and come home to roost. I will again express my belief that

* In figure 16 of tab. xxv., which Angelin described as "Brachia connata subtus visa," the arm-joints (interradials, W. & S.), which are mostly removed in fig. 15, are seen in their natural position.

† 'Handbuch der Palæontologie,' i. Band, p. 357, fig. 244 d.

‡ It would be well if the authors would explain how these "rigid" plates can have formed part of a "pliant vault" which consisted of "a continuous integument of plates connected by ligament in place of suture" (p. 65).

the small covering plates of *Crotalocrinus rugosus* are the representatives in a smaller Crinoid of the "large rigid plates" shown in figs. 6 and 7, not on pl. 6, as Wachsmuth and Springer again quote it, but on tab. viii. of Angelin's 'Iconographia;' while I shall also continue to believe, until the contrary is demonstrated, that the central plate and proximals are among the irregular pieces occupying the oral pole in the originals of these two figures, and not beneath them, although Wachsmuth and Springer "know" this latter fact "to be true."

The question of the presence or (as I believe) the absence of a flexible vault composed of calyx-interradials above the summit-plates and covering pieces of *Crotalocrinus* is one of extreme importance in the morphology of the Palæocrinoidea, for Wachsmuth and Springer's *knowledge* of its existence is employed in many cases as an argument in favour of their views respecting the great development of the *abactinal* interradianal plates of Palæocrinoids above the *actinal* side, and also for the purposes of classification.

We are told, for example, respecting *Crotalocrinus* and *Enallocrinus**:—"The summit-plates in both genera are subtegmenal, being covered completely by interradians, and the same was probably the case in the allied Ichthyocrinidæ, at least in their earlier forms. *Reteocrinus* and *Xenocrinus* were evidently in a similar condition, but it is not known whether they had summit-plates beneath the interradians or not." As I have before remarked †, the word "evidently" is here used by the authors as a short way of expressing "in our opinion." A little lower down the same page the supposed condition of *Reteocrinus* is also employed to enforce their argument:—

"It has been proved from palæontological evidence that in the earlier genera the interradians are more extravagantly developed than in later ones. In *Crotalocrinus* and *Reteocrinus* the interradians cover the entire ventral surface; in *Glyptocrinus* and *Glyptaster* they recede gradually toward the periphery, and the central space is filled by large proximals, and often by radial dome-plates. Considering these facts, is it safe to assert that in *Allageocrinus* and *Haplocrinus*, which are regarded as larval forms, interradians are entirely absent, and that all ventral plates are actinal? Is it not more reasonable to imagine that in these low forms the ventral side was covered by the one plate in a similar manner as in *Crotalocrinus*, *Reteocrinus*, and *Glyptocrinus* by the whole collection of plates? In the Neocrinoidea, from the larva to the adult, all ventral plates are actinal, but in all Palæozoic Crinoids, and we may say in all Palæozoic Pelmatozoa, the whole, or at least the

* 'Revision,' part iii. p. 57.

† Ann. & Mag. Nat. Hist. March 1886, ser. 5, vol. xvii. p. 288.

greater part, of the ventral side is abactinal, and this we consider one of the best distinctions between the two groups."

But since this somewhat extensive generalization is very largely based upon the authors' totally erroneous ideas respecting the structure of the summit in the *Crotalocrinidæ*, I do not believe that it expresses such an extremely important distinction between the Neocrinoids and the Palæocrinoids as they endeavour to make out. This passage, however, is employed as an argument to prove that the plates hitherto considered as orals in the permanent larval forms *Haplocrinus* and *Allagecrinus* * are not orals at all, but calyx-interradials which cover in the disk and, in the case of *Allagecrinus*, the summit-plates as well. But as the "extravagant development" of the interradials in the Silurian *Crotalocrinus* turns out to be an utterly erroneous theory, which has no other foundation than a complete misconception of Angelin's figures on the part of Messrs. Wachsmuth and Springer, they will have to seriously reconsider a great deal of the reasoning which they have based upon it respecting the homologies of the summit-plates in Neocrinoidea and Palæocrinoidea respectively. I have no intention, however, of taking up this discussion again at present, and I will pass on to a few words on the classification of Palæocrinoids.

Wachsmuth and Springer established the suborder *Articulata* "to include the group formerly defined by us under the family name *Ichthyocrinidæ*, with the addition of *Crotalocrinus* and *Enallocrinus*, which possess in a remarkable degree some of the most characteristic features of the group;" † and they say further on—"we think it altogether probable that the general plan of the ventral structure for the *Articulata* generally is expressed in that of *Crotalocrinus*."

I have endeavoured to show, however, that their theory as to the ventral structure of *Crotalocrinus* is altogether incorrect, owing to a faulty interpretation of Angelin's figures and to their want of personal acquaintance with the actual fossils. But the supposed existence of a flexible vault in *Crotalocrinus* is one of the reasons adduced by Wachsmuth and Springer for placing this genus among the *Articulata*, viz. those Crinoids "in which the plates of the test are united by loose ligaments or muscles, and in which they are somewhat movable" ‡. So far as my knowledge goes, however, it has yet to be proved that there was any such articulated arrange-

* "On *Allagecrinus*, the Representative of a new Family from the Carboniferous-Limestone Series of Scotland," *Ann. & Mag. Nat. Hist.* 1881, ser. 5, vol. vii. pp. 285, 286.

† 'Revision,' part iii. p. 140.

‡ *Ibid.* p. 6.

ment of the calyx-plates in the *Crotalocrinidæ* as occurs in *Forbesiocrinus* and in the *Ichthyocrinidæ* generally.

But if this proof be not forthcoming, *Crotalocrinus* and *Enalocrinus* must be removed from the *Articulata* and assigned to some other group of the *Palæocrinoidea*; and as this is a subject which I do not feel myself qualified to discuss, I prefer to leave it to the much more experienced judgment of Messrs. Wachsmuth and Springer.

There is another point in the structure of *Crotalocrinus* on which my recent observations at Stockholm enable me to throw some light, or, rather, to correct an erroneous impression which has got abroad.

On page 12 of the 'Revision,' part i. (1879), Wachsmuth and Springer wrote as follows:—

"The so-called 'consolidating-apparatus' of *Cupressocrinus* is in our opinion a true set of hydrospires, arranged in pairs exactly as in *Blastoids*, but spreading out horizontally instead of vertically. Angelin (*Iconogr. Crin.*, pl. viii. fig. 7, *a, b*) figures a *Crotalocrinus* in which the consolidating apparatus—or hydrospires, as we believe—is most excellently preserved. Even the inner tubes can be traced, and, if there still existed a doubt whether the closely related *Cupressocrinus* had its ventral side firmly closed, Angelin's figure, pl. viii. fig. 6, ought to remove it. There seems to be in *Crotalocrinus* not only a solid integument covering the entire ventral disc and inclosing the hydrospires, but we judge from fig. 7 of the preceding plate, that the oral centre or median space between the hydrospires had even a double covering."

The authors' theory that the consolidating apparatus of *Cupressocrinus* represents the hydrospires of the *Blastoids* has since been abandoned, and the explanation of its structure which they have adopted will be found on p. 178 of the 'Revision,' part iii. section 2. I have the strongest conviction that they will also have to abandon their theory as to the internal hydrospires of *Crotalocrinus*. They are singularly unfortunate in giving so many wrong references to Angelin's figures of this genus; for the one on which they rely as proving the existence of hydrospires is on tab. vii., and not on tab. viii., as they state. It is described in the explanation as follows:—"Calyx superne visus, cum parte brachii, magnitudine paullum aucta. Apparatus quem consolidantem vocant, intus visus." It is to some extent upon this figure that Wachsmuth and Springer's theory as to the existence of a pliable vault in *Crotalocrinus* was based, foreshadowed, it will be noted, as early as the year 1879.

Unfortunately, however, the figure represents not the *ventral*, but the *dorsal* aspect of the broken calyx, and

“superne” should read “inferne” in the explanation of it. This is at once evident from the fact that there are no ambulacral grooves visible upon the skeleton of the arms, such as are shown in the representations of the same species (*Crotalocrinus pulcher*) on tab. viii. figs. 6 and 7. The calyx is broken across near the level of the tops of the basals, so that the internal faces of the radials and the following plates are exposed to view, with the remarkable striations upon them which were regarded by Angelin as corresponding to the consolidating apparatus of *Cupressocrinus*. It is possible that, like this structure, they may represent an uneven surface for the attachment of muscles and ligaments; but whatever else they may be, the striæ are certainly not hydrospire-slits, as supposed by Wachsmuth and Springer in 1879. They appear to have still held this view even as late as last year, when they published the first section of the third part of the ‘Revision,’ for we find a reference to the presence of hydrospires in *Crotalocrinus* on p. 64, and on p. 83 this is extended into the following generalization:—“The Crotalocrinidæ have no ambulacral pieces, but possess hydrospires within the calyx.”

There is no mention of these hydrospires, however, in the subsequent definitions either of *Crotalocrinus* or of *Enalocrinus* in the second section of this part which has just appeared; and it is possible therefore that the authors have already given up their belief in the presence of these organs in the Crotalocrinidæ. But in any case they will no longer be able to refer to this family as Palæocrinoids which “probably have hydrospires within the calyx”*, and to use this supposed fact as an illustration of their theory that Blastoids, Cystids, and Crinoids are so closely linked together that they are not entitled to rank as Classes of Echinoderms equivalent to the Urchins and Starfishes. This point, however, is fully discussed elsewhere †.

BIBLIOGRAPHICAL NOTICES.

Revision of the Palæocrinoidea.—Part III. *Discussion of the Classification and Relations of the Brachiote Crinoids, and Conclusion of the Generic Descriptions.* By CHARLES WACHSMUTH and FRANK SPRINGER. Second Section. Extracted from the ‘Proceedings of the Academy of Natural Sciences,’ March 30, 1886. Philadelphia, 1886. Pp. 195.

WE are very glad to welcome the second and concluding section of the Revision of the Palæocrinoidea, Part III., by Messrs. Wachs-

* ‘Revision,’ part iii. p. 76.

† ‘Catalogue of the Blastoidea in the Geological Department of the British Museum (Natural History)’ (London, 1886), pp. 113-121.